SIMULATION OF DDMT'S CENTRAL PACK AREA

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Simulation of DDMT's
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DLA-LO

FOREWORD

The DLA Defense Depot Memphis Tennessee (DDMT) has for a long period operated with multiple packing operations spread across their facility. In an effort to capitalize on the economies of scale gained by consolidation and, at the same time, to upgrade operations to implement the DLA Warehousing and Shipping Procedures (DWASP), DDMT and DLA Depot Operations Support Office (DLA-DOSO) have designed a DDMT Central Packing Facility for Less Than Truckload (LTL) and bin packing. This report details the results of the simulation analysis on the proposed design to determine any problem areas and areas for improvement.

The analysis indicates that in the LTL packing operations there were three areas for concern: the small freight offer mezzanine, the small freight divert, and the multi-pallet packing area. Specific recommendations include reconfiguring the mezzanine to allow for an additional offer station, reducing processing time at divert by automation or additional operators, and reducing the number of multi-pallet packing stations from nine to three.

In the bin packing design, workload for the two input orientation stations was imbalanced, and even if balanced, resulted in a 99 percent utilization. The multi-line packing area was greatly underutilized. Specific recommendations include rearrangement of the input conveyors to balance the orientation workload, consideration of a method for increasing the capability by automation or additional operators, and reduction of the mutli-line packing stations from 95 to 75.

for John Marshall, Col, USAF
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I. INTRODUCTION

A. Background. Defense Depot Memphis Tennessee (DDMT) has for a long period of time operated with packing areas in many parts of the depot. That concept has changed recently and they are consolidating operations as much as possible to take advantage of the associated economies. In addition, the requirement to upgrade and add on equipment to support the introduction of the DLA Warehousing and Shipping Procedures (DWASP) presented the opportunity to effect the consolidatior This plan materialized in the form of the DDMT Central Pack des... for less than truckload (LTL) packing and bin packing operations.

B. Problem Statement and Study Objectives. The DLA Operations Research and Economic Analysis Office (DLA-LO) was tasked to perform a computer simulation of the proposed design for the Defense Depot Memphis (DDMT) Central Pack area. The objective of the simulation was to determine if the design could meet goal throughput and to make recommendations on system improvements and modifications.

C. Scope. This study was limited to the design of the Central Pack area of DDMT. Central Pack consists of two main areas: bin packing and LTL packing. Figure 1 provides an overview of the packing areas and the neighboring storage and transportation areas. The functions represented in the simulation for LTL included the single line/multi-pallet packing, the multi-line/single pallet packing, depalletization, offering, labeling and the dedicated truck packing. The bin packing functions that were considered in the analysis were the input orientation, attachment of the Issue/Release Receipt Document (IRRD), packing, automated weighing and offer.

D. Organization of the Report. Section II presents the conclusions for both the LTL and bin packing. Section III contains the recommendations for both areas. However, the methodologies and analyses are presented separately in Sections V and VI.

II. CONCLUSIONS. The study yielded the following conclusions:

A. For LTL Packing

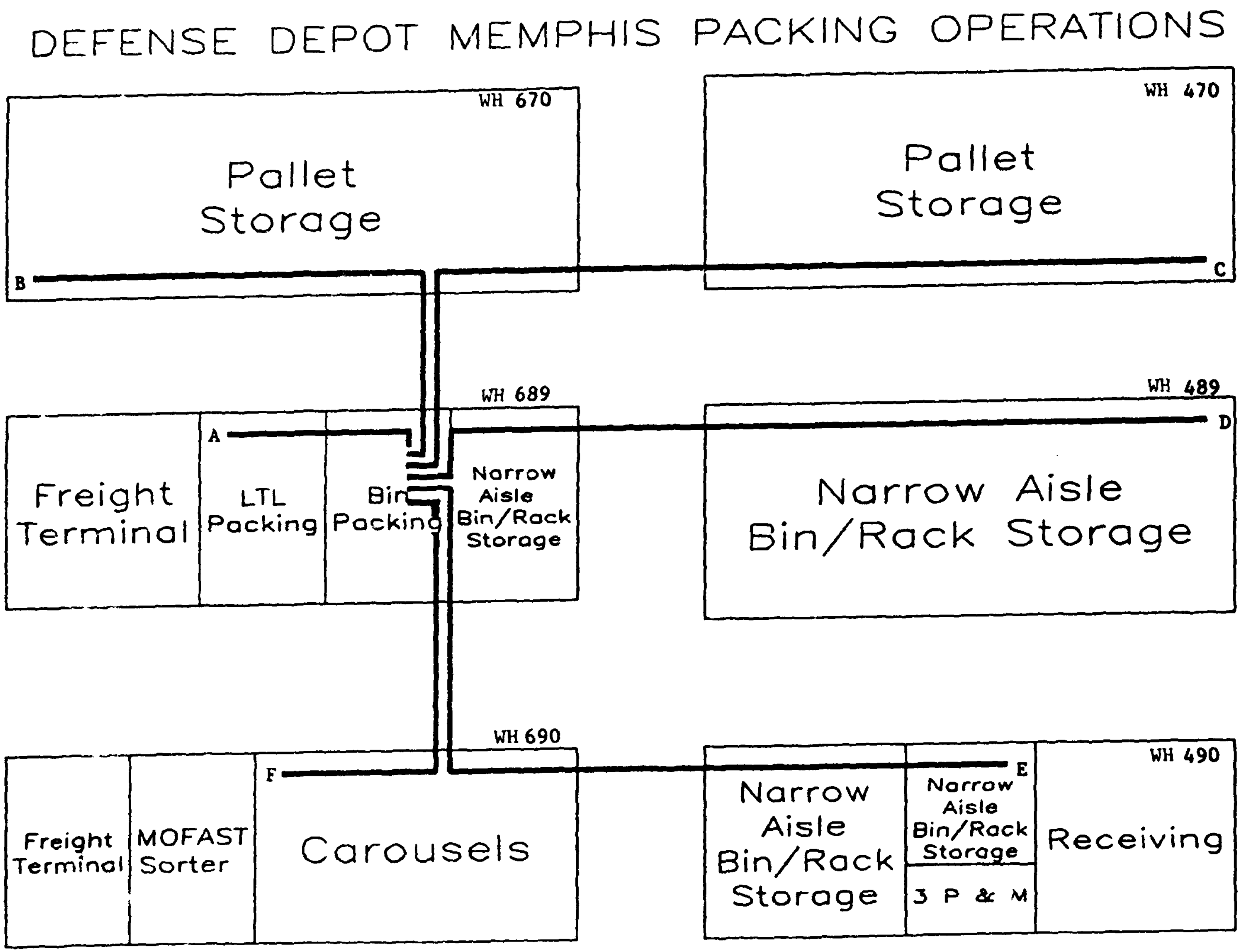
1. The single line/multi-pallet packing area is overdesigned. Three stations could handle all of the workload in this area.

2. The single pallet/multi-line packing area functioned well under the current workload scenario. The model indicated a 70% average utilization for all stations.

3. The model indicated a serious queueing problem in the area of the small freight mezzanine and the small freight divert. There is more throughput overall in this area than can be handled by the current design.

Figure 1

OVERVIEW OF CENTRAL PACK AND SURROUNDINGS



B. For Bin Packing

1. There was a significant imbalance in work for the input orientation stations. Even with balancing the workload, each station has 7.5 hours of work in a shift of 7.5 hours.

2. Mutli-line packing is underutilized. The number of chutes in this area cannot be justified based on the need for sh'pping unit separation.

III. RECOMMENDATIONS. The following recommendations are made:

A. For LTL Packing

1. Reevaluate the single line/multi-pallet packing station area and give consideration to reducing the number of packing stations to three.

2. As a minimal change, reconfigure the small freight mezzanine from one offer and three labeling stations to two offer and two labeling stations. Seriously consider increasing the size of the mezzanine to accommodate another station and have three labeling and two offer stations.

3. As a minimal change, add an additional operator to the small freight divert to reduce the processing time and to accommodate the expected throughput. Evaluate the possibility of an additional divert or a method of automating the diversion process.

B. For Bin Packing

1. Rearrange the input conveyors to the orientation stations so that workload is more balanced.

2. Consider a method for automating/reducing time for orientation.

3. Reduce multi-line packing by twenty stations.

IV. BENEFITS

The reduction in LTL single line multi-pallet packing stations would net a one time cost avoidance of approximately $200,000. Similarly, the reduction of the bin multi-line packing stations would result in a one time cost avoidance of approximately $50,000. These figures were provided by DLA-DOSO. Rerouting the conveyors in the input orientation station and in the small freight mezannine has essentially no monetary impact.

The potential monetary implications for the other recommendations depends upon the particular method of implementation. If an operator is added to the small freight divert, there is an additional recurring cost of approximately $20,000 per year based on a GS-5 salary and fringe benefits.

If the divert is automated, no operator is needed and there is a recurring cost avoidance of approximately $20,000 per year. However, automation requires additional equipment costing approximately $35,000.

In addition to the monetary benefits addressed above, the recommendations make it possible for the system to obtain the required throughput and avoid serious operational problems.

V. LTL PACKING METHODOLOGY AND ANALYSIS

A. Methodology

1. General Methodology

The general approach in this part of the study was to develop a SLAM simulation model of the Central Pack LTL packing area using design drawings and specifications obtained from DLA-DOSO. Prior to developing the simulation model, an expected value analysis was performed to establish basic flow rates, detect any immediate problem areas with the design and to aid in debugging the model itself. By using average processing times and average workload rates, expected values could be calculated for resource utilization.

The proposed design was then modeled. Although the LTL area and the bin packing area were done as individual simulations, there were areas of interface. The inputs and outputs between LTL and bin were kept consistent across the two separate simulations.

The simulation was then run to test the basic design. Later, additional runs were performed to test modifications in the basic design. The measures of performance for different alternatives were throughput, resource utilization, and queue size.

2. LTL Model Description

A schematic diagram of the LTL area and a workload flow chart are presented in Figure 2 and Figure 3, respectively. There are five main functional areas: the single line/multi-pallet packing and offer area, the multi-line/single pallet packing area, depalletization and multi-line offer area, the small freight mezzanine and the dedicated truck packing area. A brief discussion of the in-take process and the five main areas follows.

a. In-take Operator. Pallets arrive from the loading dock on a pallet conveyor to the in-take operator. The in-take operator evaluates the pallet and routes it to the appropriate packing area. Some of the pallets contain cartons which can be processed in bin packing. When the in-take operator encounters this type of pallet, he removes cartons from the pallet and places them on the package conveyor which carries them to bin packing. The remainder of the pallet as well as entire pallets are

Figure 2

SCHEMATIC OF THE LTL AREA

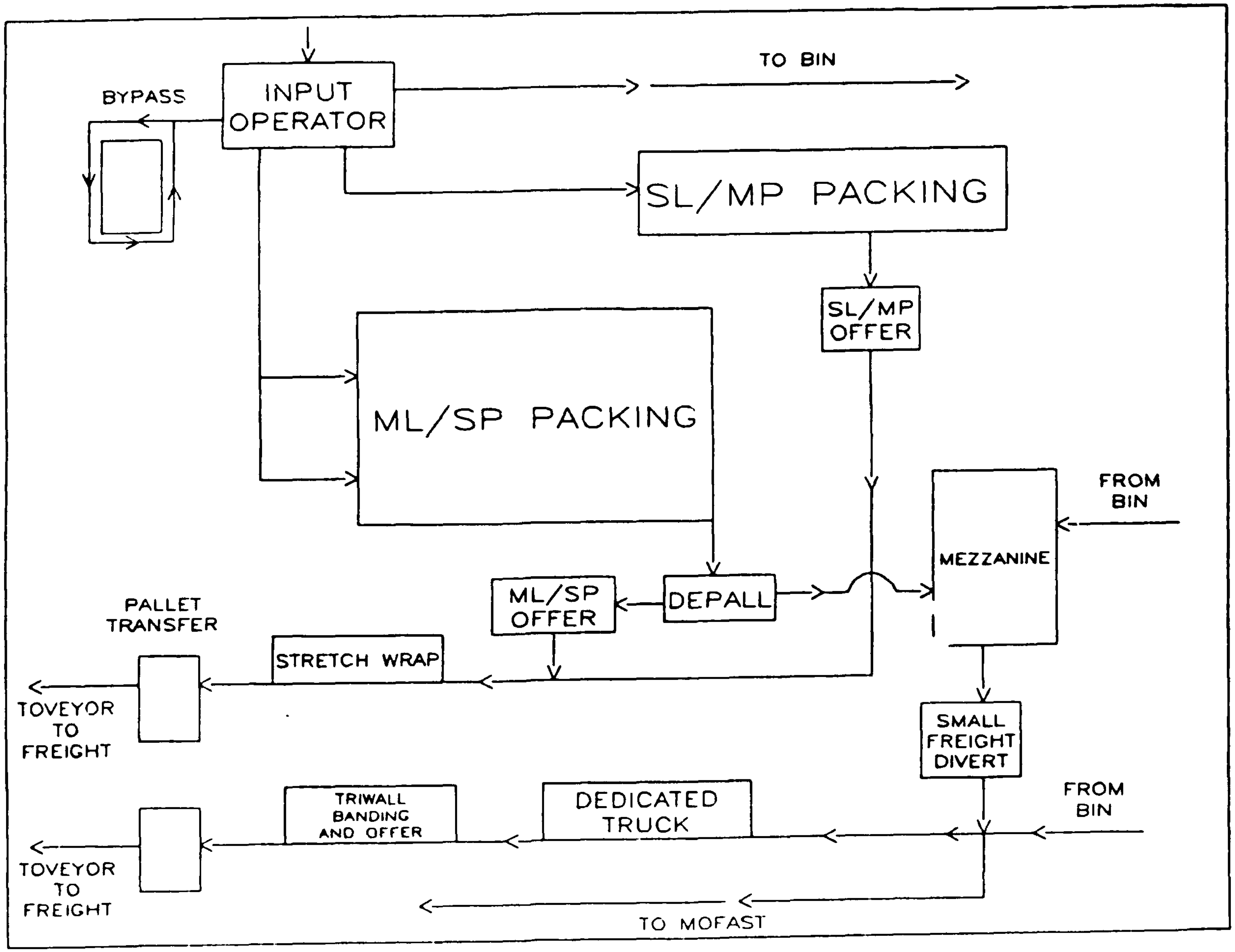
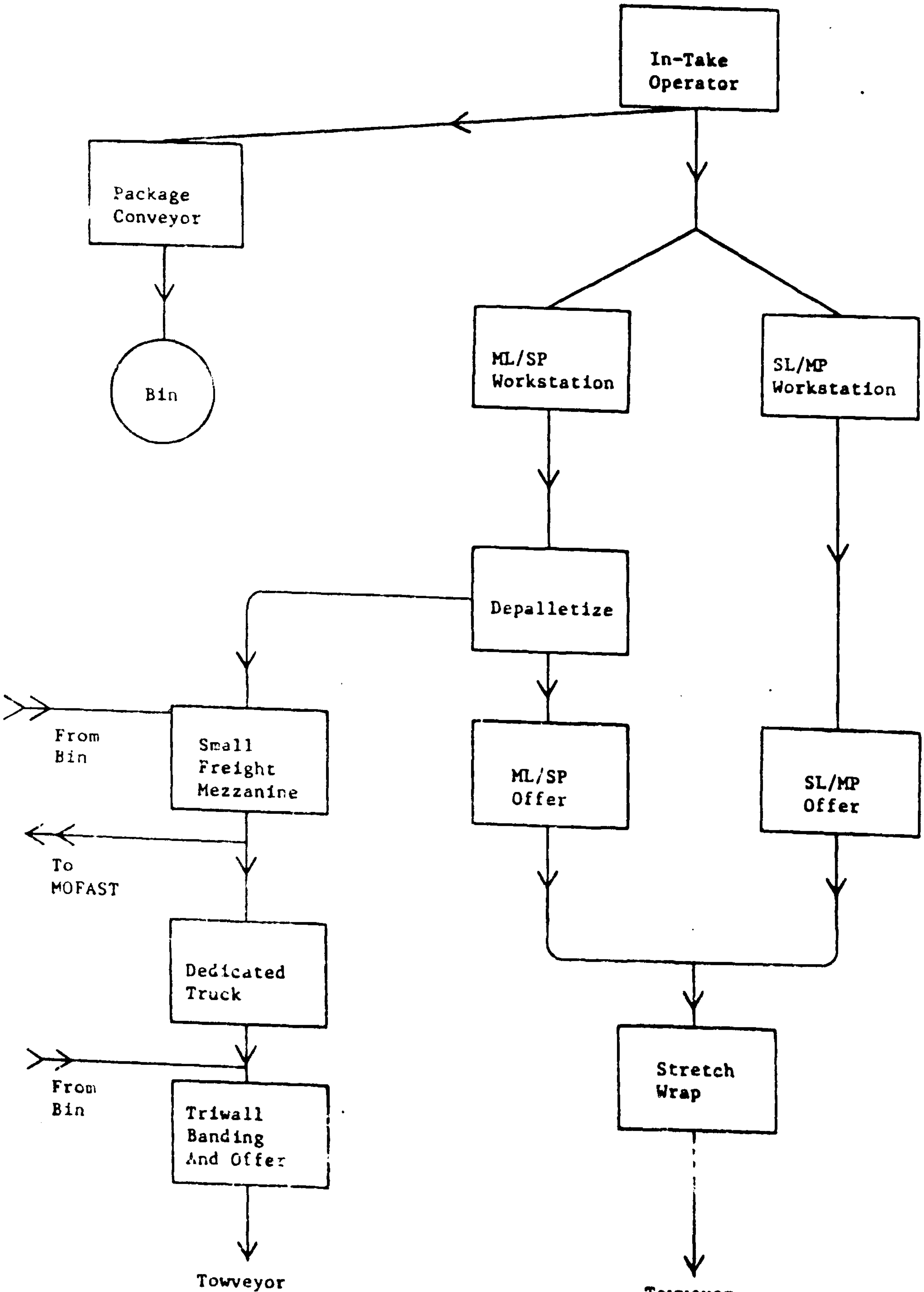


Figure 3

FLOW DIAGRAM OF THE LTL AREA



then routed to a workstation. If there are no workstations available to accept pallets from the in-take operator, the operator can utilize the by-pass line. The by-pass line consists of a loop conveyor which can accommodate pallets until there is a workstation to process them. The in-take operator can return a pallet to production from the by-pass line when a workstation becomes available.

b. Single Line/Multi-Pallet Packing and Offer

A single line on multiple pallets which arrives to the LTL area is routed to one of the single line/multi-pallet workstations. In addition, shipping units made up of multiple lines on multiple pallets are also routed to this area. These two multiple pallet configurations differ only in that single line multiple pallets are made up entirely of one type item (NSN or National Stock Number), whereas single shipping unit, multiple line, multiple pallets would be made up of more than one NSN.

Each of the single line/multi-pallet workstations has a queue capacity of five pallets. A line is routed to the first empty workstation available on a round-robin basis. When there are six or seven pallets in a single line shipping unit, two adjacent empty workstations are required. The first of the two workstations gets five pallets and the remainder of the line goes in the second workstation. If there are not two adjacent empty workstations, the line is routed to by-pass until the workstations are available.

Once the entire line reaches the workstation it is processed by the packer. The packing begins with the packer scanning the bar code called the Operational Control Number (OCN) and producing the Issue Release/Receipt Document (IRRD). The packer then checks through the pallets in the line to verify the material against the IRRD. If stenciling is required it is done at this time. Stenciling involves applying the NSN and nomenclature to any carton which does not already have these markings. When these processes are completed, the IRRD is attached and the entire line is released to offer.

The pallets proceed on a conveyor to the single line/multi-pallet offer station. At the offer station the pallets are weighed and a DoD 1387, Military Shipment Label, is attached. After the pallets are offered, they continue on the conveyor to the stretch wrap area.

At the stretch wrap area, pallets which contain items that are small or for some reason will not remain stable are wrapped with a stretch film. This secures items to the pallet. About 15 percent of all pallets processed require stretch wrapping. After the stretch wrap area, pallets proceed on the conveyor to a pallet transfer device. The pallet transfer device transfers the pallets to towveyors which carry it to the freight area.

c. The Multi-Line/Single Pallet Packing Area

Any single pallet arriving to LTL is routed to this area. (The only exceptions are pallets which are completely off-loaded to bin packing.) A single pallet can be configured in different ways. It may be a single line, single shipping unit on a single pallet. It might also be a single pallet containing multiple single line shipping units. Or it might contain several lines going to the same customer constituting a shipping unit.

The multi-line/single pallet packing area consists of 24 packing stations arranged in 3 rows of 8 stations each. The pallet conveyor from the in-take operator leads to two conveyors which feed the multi-line/single pallet packing area. The first of these conveyors feeds the first 8 stations, the second conveyor feeds the remaining 16 stations. Single pallets are routed to the packing area alternating on a two-to-one basis. Within each spur, pallets are routed in a round-robin manner. At the workstation the pallet is placed on a turntable which permits the packer access to any side of the pallet. The packer scans the OCN and produces the IRRD. The packer checks through the cartons on the pallet to verify them against the IRRD. The packer determines if stenciling is required and attaches the IRRD to the cartons.

The packer also makes a special determination at this point. The packer determines if any cartons on the pallet can be depalletized and, if so, he marks the carton for depalletization. The decision to depalletize a carton is based on the weight and cube of the carton. If a carton has a cube of less than 8 and a weight of less than 100 pounds, it is eligible for depalletization. Cartons which meet these criteria can be processed more effectively if they are removed from the pallet. The depalletization process is explained in detail in the next section. When the pallet has been completed, the operator can move it from the turntable to a take-away conveyor. Each packing station has space to accommodate a pallet in front of the turntable and behind the turntable. This feature allows the packer to stage a pallet which is ready to be worked and also one which is completed. The completed pallet will be removed by the take-away conveyor at the earliest opportunity. The take-away conveyor moves the pallet to the depalletization station.

d. Depalletization and Multi-line Offer

Pallets arriving at the depalletization station may be stopped or simply passed through to the multi-line offer area. When a pallet is stopped, cartons are removed and placed on a conveyor to the small freight mezzanine. If all the cartons are removed, then the empty pallet is conveyed to the pallet stacker. Cartons which are to be depalletized are marked at the packing station. Pallets which have been partially depalletized or passed through in their entirety proceed to the multi-line/single pallet offer area.

There are three multi-line/single pallet offer stations. Pallets are routed to the first available station in a round-robin manner. At the offer station cartons are removed from the pallet, weighed, and stacked onto another pallet. These stations are equipped with a package transfer crane to assist the operator in moving heavy cartons. When all the cartons have been weighed and the Military Shipment Label has been attached to the pallet, the pallet is placed on a take-away conveyor which carries it to the stretch wrap area. If the pallet required stretch wrapping, the operator at the offer station will designate this.

Pallets which are stretch wrapped and pallets which by-pass the stretch wrap process proceed on a conveyor to the pallet transfer device where they are transferred to a towveyor. The towveyor carries pallets to the freight terminal.

e. The Small Freight Mezzanine. This four workstation area is used to offer or label cartons. Cartons arrive from two sources-from LTL and from bin. Cartons which are depalletized from multi-line/single pallets are sent to the mezzanine to be offered. Additionally, cartons going freight arrive at the mezzanine from bin packing. Generally there are two categories of cartons arriving from bin, those which are going via the Enhanced DLA Distribution System (EDDS), and those to be consolidated with triwalls for dedicated truck shipments. These cartons from bin have already been offered and simply are labeled at the mezzanine. Cartons leaving the mezzanine are routed to the small freight divert. At this point cartons are diverted to either the EDDS sorter or the dedicated truck packing area.

f. The Dedicated Truck Packing Area. Every depot has large volume shipments to particular destinations. The dedicated truck area is designed to accommodate these destinations. There are six packing stations in this area. Cartons are routed to one of six packing chutes, where a packer places the carton in a triwall. When a triwall is filled a tilt table moves the triwall to a pallet conveyor. The pallet proceeds on the pallet conveyor to an in-line banding machine where it is banded and finally to the triwall offer process and out to the freight terminal. Also proceeding on the pallet conveyor are triwalls arriving from the bin area, already packed, which need to be banded and offered before going to the freight terminal.

3. <u>Data Development</u>

Equipment characteristics and time standards were provided by DOSO and are presented in Table 1. The numbers in parentheses are the minimum, most likely, and maximum processing times. A triangular distribution was used to represent these times.

The F042 report (Summary Analysis of Released Workload) a daily report from the MOWASP system, was used to gather data on the current workload. It presents data on individual shipping units and contains number of lines, total weight and cube, and transportation mode (freight or non-freight).

Table 1

LTL CRITICAL STATION TIMES

PROCESS		TIME
OPERATOR:		
	KEY PALLET	10 SECONDS
	REMOVE ITEMS FOR BIN (PER LINE)	(9.3,9.8,10.3)
SINGLE LINE/MULTI PALLET AREA:		
	PROCESS A LINE AT A WORKSTATION	(265.5,279.5,293.4)
	OFFER A PALLET	56 SECONDS
MULTI LINE/SINGLE PALLET AREA:		
	PROCESS A LINE AT A WORKSTATION	(297.0,312.6,328.3)
DEPALLETIZATION:		
	ASSESS A PALLET	3 SECONDS
	REMOVE A CARTON	(9.3,9.8,10.3)
MULTI LINE/SINGLE PALLET OFFER:		
	OFFER A SU	(83.3,87.7,92.1)
SMALL FREIGHT MEZZANINE:		
	PERFORM SMALL FREIGHT OFFER (PER DEPALLETIZED CARTON)	48 SECONDS
	LABEL CARTONS (PER CARTON FROM BIN PACKING)	28 SECONDS
SMALL FREIGHT DIVERT:		
	DIVERT TO MOFAST OR DEDICATED TRUCK	(11.8,12.5,13.2)
DEDICATED TRUCK:		
	PERFORM PACKING (PER CARTON)	10 SECONDS
	BAND A TRI-WALL	60 SECONDS
	OFFER A TRI-WALL	(54.7,57.6,60.5)

Reports for a period from 11 July 1988 to 2 September 1988 were compiled to establish the average number of lines processed per day, the weight and cube of the shipping units, the percentage of freight, and the percentage of shipping units that are single line versus multi-line.

The designed workload for the LTL packing area is 3200 lines per day coming in to the in-take operator. The averages from the F04? report analysis were proportioned to the 3200 line per day figure. ' f he 3200 lines arriving per day, 1610 lines would be off-loaded to t... package conveyor to go to bin. The remaining 1590 lines would be processed in the LTL area.

The F042 reports were further processed to determine the number of single line/multi-pallets and multi-line/single pallets. Using 52.8 as the total cube for a pallet it could be determined which shipping units would consist of one pallet, two pallets, etc. Shipping units which did not exceed the cube for a single pallet were those which would be processed in the multi-line/single pallet area. The summary results of this determination are shown in Table 2.

Certain assumptions were made in processing this data to determine workload for LTL packing. It was assumed that single line freight shipping units would be consolidated on a pallet, with no more than 10 shipping units on a pallet and a maximum cube of 35. When a multi-line/single pallet was depalletized an entire shipping unit would be removed. Furthermore, multi-line shipping units would not be mixed on a pallet.

To determine the rate of depalletization, all of the freight shipping units were screened by weight and cube. Of the total number of lines input about 600 should be depalletized per shift.

B. ANALYSIS

1. Throughput Requirements and Baseline Results. The baseline LTL system is designed to process 3200 lines arriving to the in-take operator on approximately 400 pallets per shift. In addition, 7000 lines arrive from bin per shift. These lines arrive to the small freight mezzanine as individual cartons, and to the triwall banding and offer area as triwalls. Figure 4 is a flowchart which illustrates the required throughput. Table 3 provides the resource utilization of the baseline design as calculated from the model runs. The detailed analysis of each main functional area and the recommended changes are discussed in the following sections.

2. In-Take Operator. The in-take operator has two main functions. These are routing pallets to the appropriate workstation and off-loading cartons from pallets to the package conveyor. The simulation indicated a utilization rate for the in-take operator of 75%. The in-take operator has the option of using the by-pass conveyor. Having this option eliminates potential problems that might be caused by irregular input flow. Modifications to this area were not indicated by the simulation.

TABLE 2

F042 DATA - DDMT

8 DAY AVERAGE

	TOTAL SU	TOTAL LINES	SU $<$100 LBS $<$8 CUBE	SU $<$10 CUBE	SU 10-50 CUBE	SU $\geq$50 CUBE
SING FRT	255	255	161	202	45	8
SING NON-FRT	923	923	923	923		
MULTI FRT	170	1336	56	80	74	16
MULTI NON-FRT	195	686	184	189	6	
TOTAL	1543	3200				

Figure 4

REQUIRED THROUGHPUT

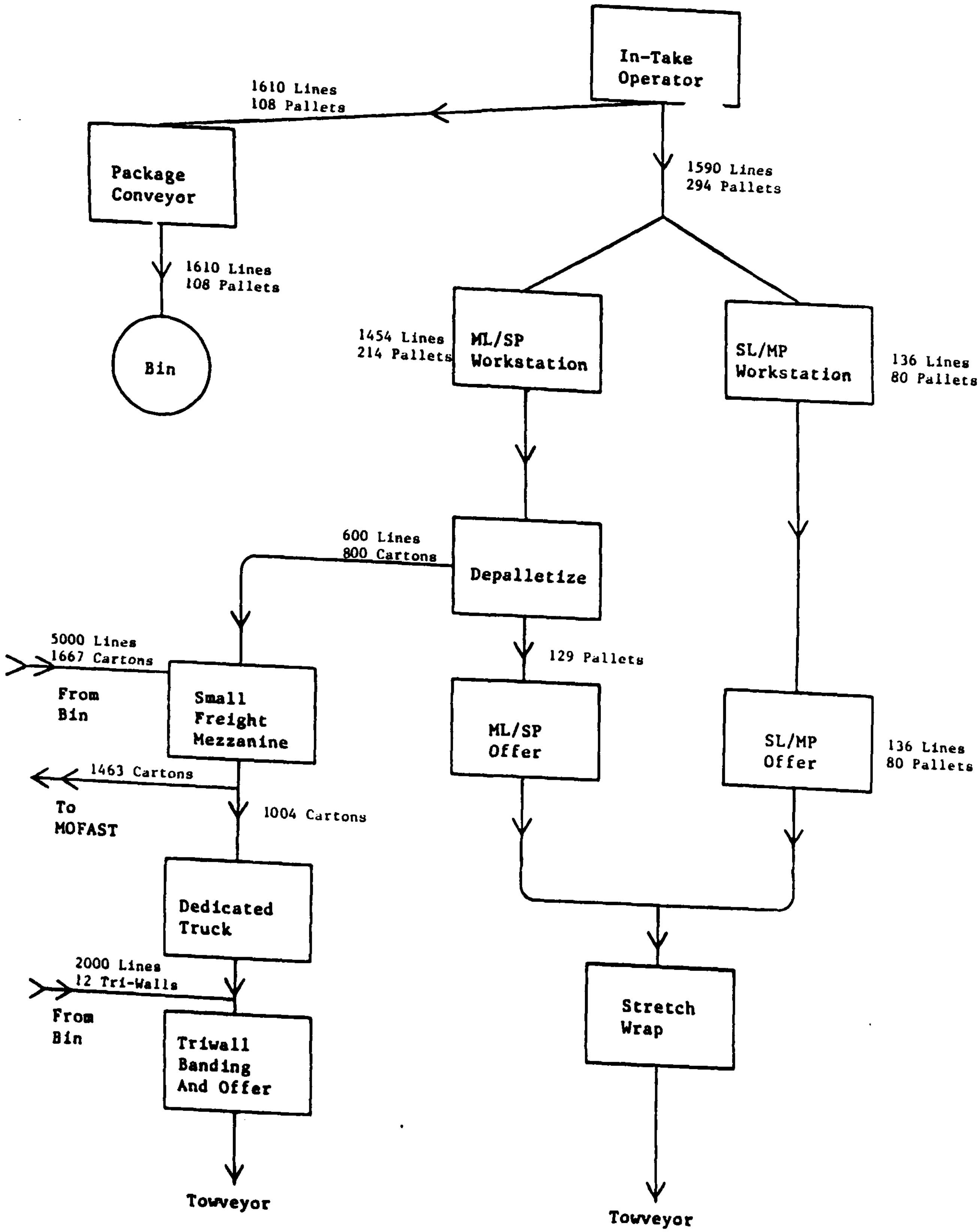


Table 3

RESOURCE UTILIZATION

	Design As Proposed
In-Take Operator	.75
Single Line/Multi-Pallet Workstation # 1	.19
# 2	.18
# 4	.19
# 6	.18
# 8	.17
# 9	.16
Single Line/Multi-Pallet Offer Station	.19
Multi-line/Single Pallet (24 station average)	.70
Multi-line/Single Pallet Offer Station # 1	.19
# 2	.18
# 3	.20
Stretch Wrap (per machine)	.05
Depalletization Station	.22
Small Freight Mezzanine Station # 1	.98
# 2	.58
# 3	.58
# 4	.58
Small Freight Divert	.82
Dedicated Truck (6 stations average)	.07
In Line Tri-wall Banding	.04
Tri-Wall Offer Station	.04
Pallet Transfer # 1	.48
Pallet Transfer # 2	.03

3. Single Line/Multi-Pallet

One fact that is very evident from the model results is the low utilization of the nine single line/multi-pallet workstations. The proposed design calls for the in-take operator to route pallets to the nine stations in a round-robin manner. Approximately 136 lines on 80 pallets will be processed in this area per shift. To examine the imp- - of reducing the number of stations, we ran the simulation with three :t- :ions. The utilization data for the proposed design and the design with recommended changes is presented on Table 4.

Basically, the throughput could be handled by three stations with no adverse effects. The only change occurred is the occasional (once per shift) use of the by-pass conveyor when two adjacent free stations are not available to accept a six or seven pallet order. In this case, the operator would have to route these pallets to by-pass until the stations were available.

The one single line/multi-pallet offer station easily handles the entire throughput as designed.

4. Multi-Line/Single Pallet Packing and Offer Stations

The proposed design for LTL specifies 24 multi-line/single pallet work-stations. To analyze the performance of these stations the simulation was run using the 3200 lines expected throughput. Of the 3200 lines coming to the in-take operator, about 1450 lines on 215 pallets go through the 24 multi-line/single pallet stations. The average utilization in this area is 70%, which was fairly uniform across all of the stations. Modifications were not indicated by the simulation analysis for this area.

The offer stations will handle approximately the same number of pallets as are processed by the multi-line single pallet workstations, that is 215 per shift. This number will be decreased somewhat by the removal of pallets which are totally depalletized. The simulation indicated a 20 percent utilization for each of the three offer stations. The simulation was also run to test the performance of this area with two offer stations. The utilization increased to 30 percent per station and there was no indication of any adverse effects.

If three offer stations are ultimately used, another alternative could be considered. This would be to allow one or two of the offer station operators to jockey between those stations and the stretch wrap area. The stretch wrap area is discussed in more detail below.

Table 4

RESOURCE UTILIZATION

	Design As Proposed	Design With Recommended Changes
In-Take Operator	.75	.75
Single Line/Multi-Pallet Workstation # 1	.19	.53
# 2	.18	.55
# 3	.19	.48
# 4	.19	.0
# 5	.17	.0
# 6	.18	.0
# 7	.18	.0
# 8	.17	.0
# 9	.16	.0
Single Line/Multi-Pallet Offer Station	.19	.19
Multi-line/Single Pallet (24 station average)	.70	.70
Multi-line/Single Pallet Offer Station # 1	.19	.31
# 2	.18	.29
# 3	.20	.0
Stretch Wrap (per machine)	.05	.05
Depalletization Station	.22	.31
Small Freight Mezzanine Station # 1	.98	.74
# 2	.58	.74
# 3	.58	.86
# 4	.58	.86
Small Freight Divert	.82	.92
Dedicated Truck (6 stations average)	.07	.07
In Line Tri-wall Banding	.04	.04
Tri-Wall Offer Station	.04	.04
Pallet Transfer # 1	.48	.48
Pallet Transfer # 2	.03	.03

5. Stretch Wrap and Pallet Transfer

The simulation indicated that the two stretch wrap machines can easily handle the expected wrapping requirements. The average utilization per machine was 5 percent. This was based on an expectation of 15 percent of all pallets needing stretch wrapping. Even if this figure of 15 percent is conservative, the stretch wrapping facilities are more than adequate, and probably would not require full-time operators. Howe er backup capability might be needed in case one of the machines is down fc service.

The pallet transfer devices transfer the pallets from the conveyors to the towveyors. The simulation indicated that the pallet transfer device which followed the stretch wrap area would have a 48 percent utilization. This transfer device would essentially be handling all of the pallets packed and offered in the single line and multi-line packing areas. The other pallet transfer device only handles triwalls. The simulation indicated that this device would have a 5 percent utilization rate, consistent with the low utilization rates in the triwall area. A single full-time operator could easily satisfy the work requirements in this area.

6. Depalletization, Small Freight Mezzanine, Small Freight Divert

The depalletization station, the small freight mezzanine and the small freight divert are closely interrelated areas. The utilization percentages associated with these stations indicate some potential problems; however, further analysis of the simulation indicated even more problems.

Every pallet processed in the multi-line/single pallet area must pass through the depalletization station. At this station a pallet can be passed through to multi-line/single pallet offer or cartons on it can be depalletized. When cartons are depalletized, they are placed on an inclined conveyor which carries them to the small freight mezzanine. The total capacity of the offer station is around 540 cartons per shift. The expected throughput for this offer station is about 35% more than that capacity. The simulation indicated that the offer station would have cartons waiting in a queue behind it. In the physical design the only space for queueing is on a short conveyor with a limited capacity of about 20 cartons. There is no provision for cartons to go anywhere else. The operator at the depalletization station would have no other choice but to pass entire pallets through to multi-line/single pallet offer. Cartons which were designated to go to the dedicated truck stations or to the EDDS sorter will now remain on the pallet. The simulation indicates that 300 cartons designated for depalletization would not be depalletized due to the excessive queueing. These would be forced to be offered in the multi-line/single pallet area.

To resolve this problem we modified the configuration of the small freight mezzanine. The original design calls for one offer station and three labeling stations. The recommended design is two offer stations and two labeling stations. This change requires minimal design modification in that it would mean the addition of a scale and the re-routing of one conveyor. The utilization rates are presented on Table 4 and the

throughput is contained in Table 5. This change helps to solve the throughput problem at the depalletization station. With this configuration, the simulation indicates that less than one pallet per shift would have to be forced past depalletization due to a backup of cartons on the conveyor to the mezzanine.

Table 5

IMPACT OF SMALL FREIGHT MEZZANINE CONFIGURATIONS

	1 Offer Station/ 3 Label Stations	2 Offer Stations/ 2 Label Stations
Depalletization Station		
Pallets throughput	220	220
Pallets evaluated and processed	150	220
Pallets passed through (not evaluated or processed)	70	0
Cartons removed	540	810
Small Freight Mezzanine		
Cartons offered and labelled (from depalletization)	540	810
Cartons labeled (from Bin Packing)	1668	1668

About 7000 lines per shift arrive to the LTL packing area from bin packing. Of these lines, 5000 arrive to the small freight mezzanine and the other 2000 are packed in triwalls. The 5000 lines arrive in 1667 cartons (3 lines per carton). If the configuration of the small freight mezzanine is modified as recommended, the utilization rate for the two label stations would be 86% (see Table 4). The stations will handle the specified workload but there is not much allowance for variation in the flow to the mezzanine. During simulation runs, we kept the flow from the bin packing fairly uniform. If the number of cartons increased due to more lines arriving, or less lines per carton, the capacity of these two stations could be exceeded. In any case, the small freight mezzanine will experience a large amount of throughput and has a quite high utilization rate.

Another possible bottleneck area is the small freight divert. The design as proposed calls for the divert to have a single operator and process cartons at a rate of 12.5 seconds per carton. The small freight mezzanine has the capability of releasing a carton every 8 seconds. The mezzanine and the divert are connected by approximately 50 feet of elevated conveyor, which does not allow for the queuing of cartons behind the divert. The initial runs of the simulation indicated serious queuing backup. The queue that will form behind the divert will shut down the mezzanine, the incoming conveyor from bin packing, and the depalletization station. It is essential that this situation be alleviated.

It may be possible to reduce the process time at the small freight divert by the addition of another operator to assist the first operator. This new operator could orient cartons and call out the code number to be keyed in by the other operator. DOSO has suggested that this could reduce the time to process a carton to 7.5 seconds. This faster process time would be adequate to handle the maximum output from the small freight mezzanine. However, because arrival time and processing time at he divert are so close, any inconsistency could cause a queue to form (see Table 6). Note the throughputs are the maximum possible under the two designs.

It is important to note that analysis of all of the simulation runs indicates that selective changes in the areas of the small freight mezzanine or the small freight divert will not solve the queuing problem but merely shift the bottleneck from one point to another.

Table 6

MAXIMUM POSSIBLE
CARTON THROUGHPUT FROM MEZZANINE TO DIVERT

	Proposed Design	Recommended Design
Small Freight Mezzanine Maximum output (per hour)	461	407
Small Freight Divert Maximum throughput (per hour)	288	480
Queue after one hour	173	None
Small Freight Divert Total throughput per shift		
Maximum capacity	2160	3600
Expected throughput	2500	2500

7. Dedicated Truck Packing Area

The analysis indicated that the dedicated truck packing stations would have a utilization of 7 percent on the average. Associated functions such as triwall banding and triwall offer would also have very low utilization rates. These utilization rates are presented at the bottom of Table 4. The simulation indicated that approximately 12 triwalls would arrive from the bin packing area per shift. The number of triwalls will vary as the number of lines sent from bin varies between those sent in triwalls and those sent in cartons. The dedicated truck packing stations generate seven triwalls per shift. In all there will be 20 triwalls per shift requiring banding and offering. In order to examine a maximum workload scenario,

some simulation runs were performed using twice the expected throughput of triwalls. Even in this situation, the number of triwalls processed remained so low that the impact was not significant.

The analysis of this area indicates that full-time manning of all stations is not necessary. It is very possible that operators could jockey between packing stations and even the banding and offer stations without falling behind.

VI. BIN PACKING METHODOLOGY AND ANALYSIS

A. Methodology

1. Background. The DDMT design, is basically the same as the Defense Depot Ogden Utah (DDOU) design studied under a previous DLA-LO project (Project No. 6034). However, there are some significant differences. These are:

a. Automated Weighing and Offer (AWOS) stations incorporated to reduce the manpower requirement in the offer area.

b. The initial input of items to the system is provided by a series of six conveyors instead of one.

c. The number of packing stations has increased significantly.

d. There are ten triwall packing stations.

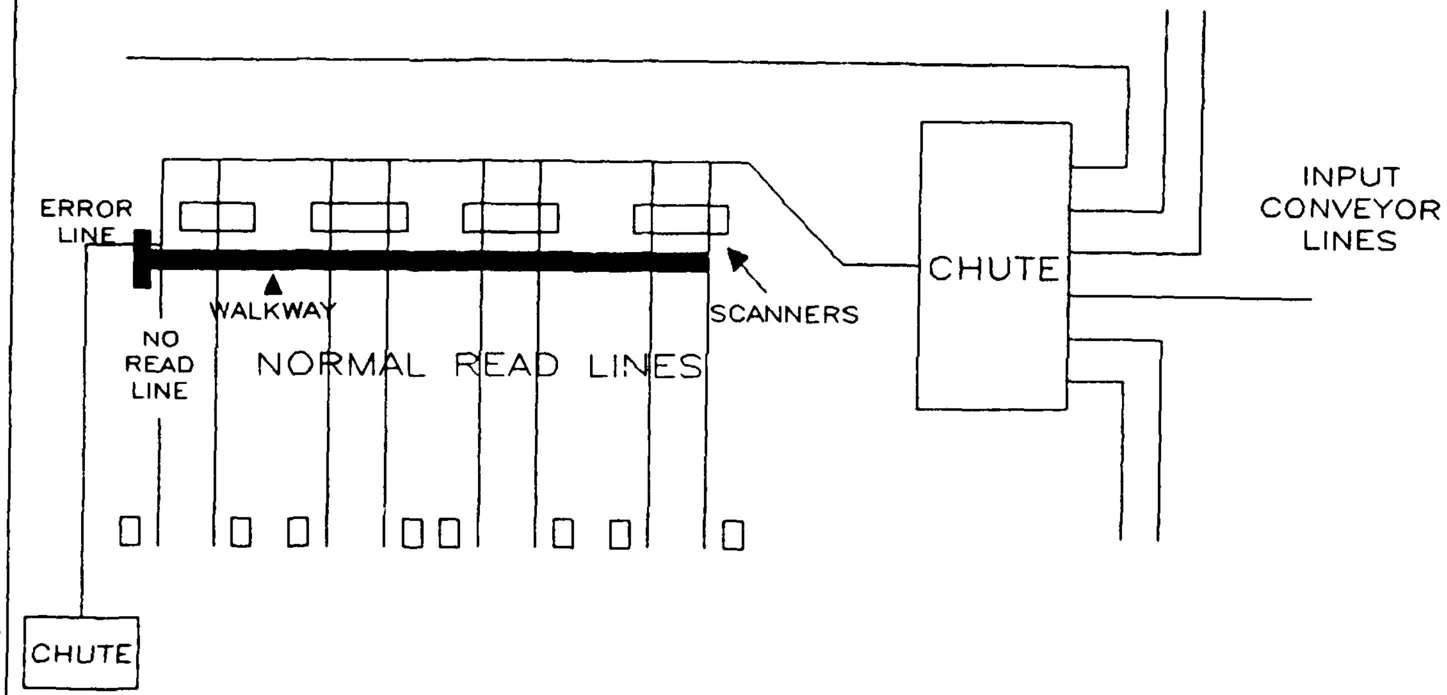
The model was quite similar to that used in the DDOU DWASP bin packing and offer simulation analysis and major portions of that code were reutilized.

2. Model Description. Under the Central Pack concept the packing for several areas of the depot is concentrated in a single location. To accomplish this, conveyors route the bin material to packing from neighboring buildings. A schematic of the areas serviced by the central pack is provided in Figure 1. A more detailed schematic diagram of the packing and offer station area is presented in Figures 5 and 6. Note that the IRRD area is on a mezzanine above the AWOS stations. There are six main functional areas depicted - input orientation, the IRRD mezzanine, single line packing, multi-line packing, AWOS stations, and final label stations. Each of these is discussed below after a brief overview of the picking operation.

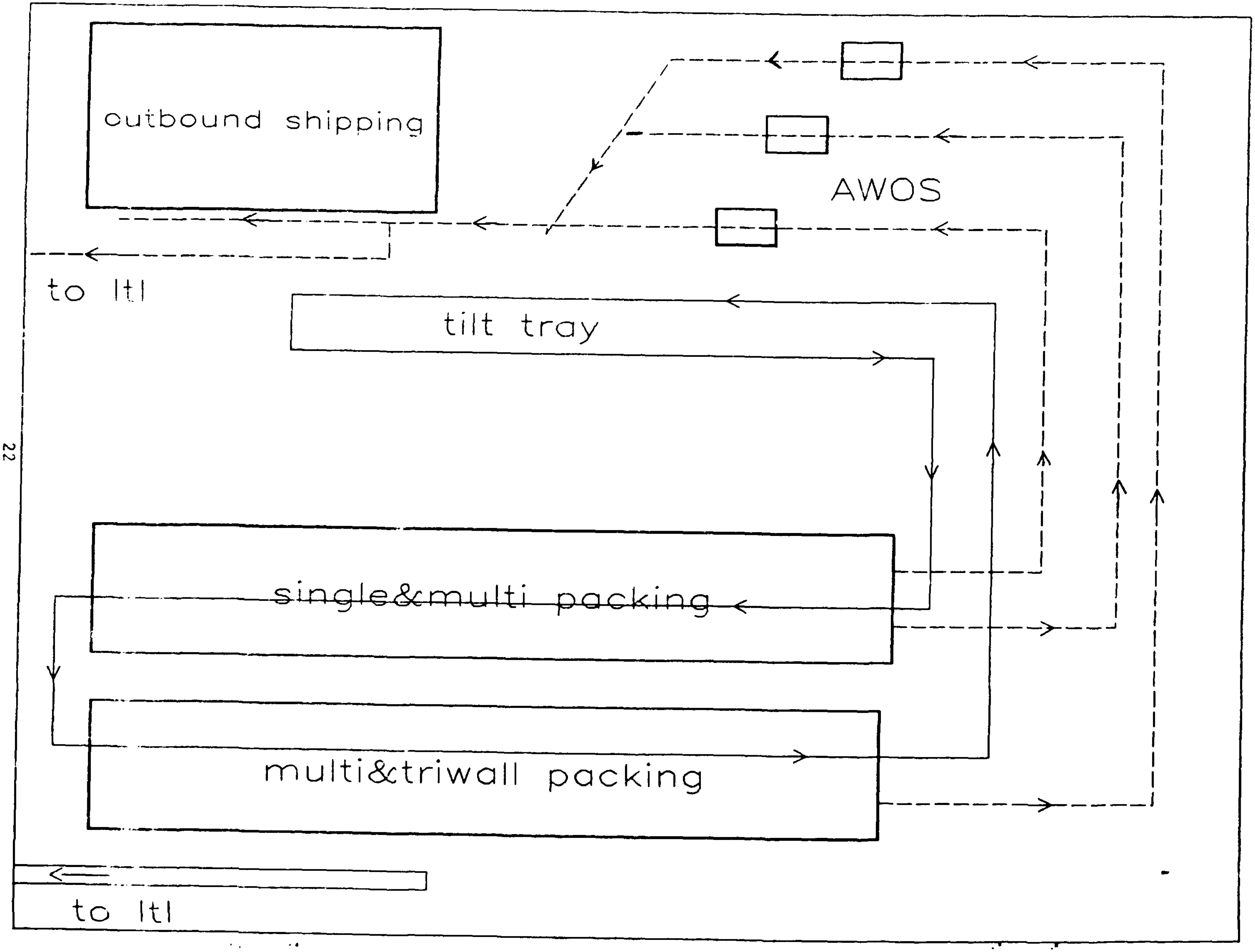
a. Picking and Packing Assignment. Customer requisitions that are to be picked for a given day are organized into several batches or cycles of stock selection. DDMT uses four batches of picks, one for Issue Priority Group (IPG) 1, one for IPG 2, and two for IPG 3. All the requisitions within an IPG group that are destined to be packed for a given customer are consolidated into a unit called a shipping unit. The shipping units within each batch are assigned to a specific packing chute at the beginning of the day.

Figure 5

SCHEMATIC OF IPRD MEZZANINE



SCHEMATIC OF BIN PACKING



b. Input Orientation and IRRD Mezzanine

Once an item is picked for a customer, a pick ticket (Figure 7) is attached that contains a bar code called an Operational Control Number (OCN). The OCN is used to determine which shipping unit the package belongs to, which packing chute is its destination, and what information is to accompany the item. Once they are picked, the items, usually in small bags or cartons, are placed on a conveyor to be brought over to the pac..ig area. Once they reach the bin packing area they are dumped into a chut .o then be oriented with the OCN upward so that it can be scanned by bar code readers along the way. The design calls for two orientation stations at either end of the chute with a takeaway conveyor in between the two stations.

Once the container is oriented and spaced properly on the conveyor, the conveyor brings the item to the first scanner. If for some reason the OCN cannot be scanned, the item is diverted down the exception processing lane and processed manually. Otherwise, it is diverted down one of the IRRD lanes and scanned again. At this point a signal is sent to the printer at the end of the lane to print the IRRD. The IRRD (Figure 8) contains information on the name, quantity, etc. of the item. When the item reaches the actual IRRD station the operator removes the IRRD from the printer, matches the IRRD with the item, staples the IRRD onto the item and places it on the tilt tray sorter to be taken away to the assigned packing chute.

c. Single Line Pack Stations. If the item is the only item in the shipping unit, the tilt tray sorter will take it to one of the 10 single line packing stations. There the item is packed and then put on a takeaway conveyor which transports it to the offer area.

d. Multi-line Pack Stations

Items that are part of a multi-line shipping unit are dropped off at one of the 95 multi-line packing stations. Large shipping units that must be packed in triwalls are sent to one of the 10 stations capable of packing triwalls. However, these stations can also pack non-triwall shipping units. Once triwalls are completed, they move directly to the LTL offer area and do not travel to the AWOS in the bin area.

Any items that were not dropped off by the tilt tray sorter because of a mechanical problem with the sorter or a bad bar code are brought back to the IRRD mezzanine and processed by the exception line.

At a station, the packer uses the DWASP system to identify which container the item is to go into and whether the shipping unit is complete or not. A bar code label OCN is placed on each carton at the packing area to identify the shipping unit contained in the carton. Once the shipping unit is complete the packer places the cartons on the takeaway conveyor that transports them to the automatic sealer in the offer area.

Figure 7

PICKING TICKET WITH BAR CODE

```
156-07-67-AA  5310-00-061-7326
155-03-18-DA     NUT STL
                  1  HD  CC-A
                  UP 00003.71
 PRES & PACK C/C
                    * IPG 3 *
DATE   PDT
8013   014        UNIT PACK 00000
                  LI QTY 00001
0131728-8
0016 OF 0028
  FRT

SHIP EXACT QTY

NO APPLICABLE CODE
NO SPECIAL CODE APPL

  SU-S16    TU-S16
BN-13    RESTART 00914      L          04YS1
```

```
156-08-20-JA  5310-00-962-5864
                  WSHR ALM
                  20  EA  CC-A
                   UP 00000.46
 PRES & PACK C/C
                    * IPG 3 *
DATE   PDT
8013   014        UNIT PACK 00001
                  LI QTY 00000
0132507-8
0031 OF 0056
  FRT

NO APPLICABLE CODE
NO SPECIAL CODE APPL

  SU-S16    TU-H6
BN-13    RESTART 00915      L          050V2
```

```
156-08-22-LA  5935-00-817-4602
                  CONNECTOR
                   3  EA  CC-A
                   UP 00001.28
 PRES & PACK C/C
                    * IPG 3 *
DATE   PDT
8013   014        UNIT PACK 00001
                  LI QTY 00000
0131728-8
0017 OF 0028
  FRT

SHIP EXACT QTY

NO APPLICABLE CODE
NO SPECIAL CODE APPL

  SU-S16    TU-S16
BN-13    RESTART 00916      L          04YS2
```

```
156-08-29-GA  5340-00-699-8463
                  CLIP STL
                   1  EA  CC-A
                   UP 00000.30
 PRES & PACK C/C
                    * IPG 3 *
DATE   PDT
8013   014        UNIT PACK 00001
                  LI QTY 00000
0132798-4
0085 OF 0147
  FRT

NO APPLICABLE CODE
NO SPECIAL CODE APPL

  SU-S16    TU-R3
BN-13    RESTART 00917      L          0511X
```

Figure 8

ISSUE RELEASE/RECEIPT DOCUMENT

DOC IDENT	RI FROM	M & S	UNIT ISS	QUANTITY	SER	SUPPLEMENTARY ADDRESS	SIG	FUND	DISTRIBUTION	PROJECT	PRI	REQ'D DEL DATE	ADV	RI	O/P	COND	MGT	UNIT PRICE DOLLARS	CTS	1 TOTAL PRICE DOLLARS	CTS
A5A	SUG	K	PG	00001			A	6C	01			12		2DS	9	G	AA	00004	13	000004	13

2 SHIP FROM: SW3400

3 SHIP TO: 678822

4 MARK FOR

5 DOC DATE	6 NMFC	7 FRT RATE	8 TYPE CARGO	9 PS
8025	179060	LT0085.0	Z92	U

10 QTY REC'D	11 UP	12 UNIT WEIGHT	13 UNIT CUBE	14 UFC	15 SL
	001	00000.00	000.00		0

16 FREIGHT CLASSIFICATION NOMENCLATURE

17 ITEM NOMENCLATURE

PINRECORD

18 TY CONT	19 NO CONT	20 TOTAL WEIGHT	21 TOTAL CUBE

22 RECEIVED BY	23 DATE RECEIVED

24 DOCUMENT NUMBER & SUFFIX (30-44)

FB466180160226

25 NATIONAL STOCK NO & ADD (8-22)

6685011121919

26 RIC (4-6) UI (23-24) QTY (25-29) CON CODE (71) COG (55-56) UP (74-80)

S9GPG00001A010000413

27 ADDITIONAL DATA

0222747000100-9

OCN-06YMF

004

DD FORM 1348-1A, JUN 86 ISSUE RELEASE/RECEIPT DOCUMENT

FORM APPROVED, OMB NO 0704-0188

DOC IDENT	RI FROM	M & S	UNIT ISS	QUANTITY	SER	SUPPLEMENTARY ADDRESS	SIG	FUND	DISTRIBUTION	PROJECT	PRI	REQ'D DEL DATE	ADV	RI	O/P	COND	MGT	UNIT PRICE DOLLARS	CTS	1 TOTAL PRICE DOLLARS	CTS
A5A	SUG	K	PG	00001			A	6C	01			12		2DS	9	G	AA	00004	13	000004	13

2 SHIP FROM: SW3400

3 SHIP TO: 678822

4 MARK FOR

5 DOC DATE	6 NMFC	7 FRT RATE	8 TYPE CARGO	9 PS
8025	179060 B	LT0085.0	Z92	U

10 QTY REC'D	11 UP	12 UNIT WEIGHT	13 UNIT CUBE	14 UFC	15 SL
	001	00000.00	000.00		0

16 FREIGHT CLASSIFICATION NOMENCLATURE

17 ITEM NOMENCLATURE

PINRECORD

18 TY CONT	19 NO CONT	20 TOTAL WEIGHT	21 TOTAL CUBE

22 RECEIVED BY	23 DATE RECEIVED

24 DOCUMENT NUMBER & SUFFIX (30-44)

FB466180160226

25 NATIONAL STOCK NO & ADD (8-22)

6685011121919

26 RIC (4-6) UI (23-24) QTY (25-29) CON CODE (71) COG (55-56) UP (74-80)

S9GPG00001A010000413

27 ADDITIONAL DATA

0222747000100-9

OCN-06YMF

004

DD FORM 1348-1A, JUN 86 ISSUE RELEASE/RECEIPT DOCUMENT

FORM APPROVED, OMB NO 0704-0188

Not all stations are manned at all times. The scheme for manning the chutes was determined by a series of model runs so that each packer had essentially the same amount of work and had moderate utilization. Thus the packers were allowed to jockey from chute to chute on an as-needed basis. The reason for the large number of chutes is to assist in shipping unit separation. A chute can contain multiple shipping units at a time. If the number of shipping units in a given chute is excessive, the packer spends a significant amount of time keeping the units separated. Confusion resulting from a large number of units in the packing chute at the same time also increases the risk of an item being placed in the wrong carton.

e. Offer Stations

There are three automatic weighing and offer stations (AWOS). One services the single line shipping units and the others the multi-line. For the multi-line stations dunnage dispensers and carton sealers complete the packaging before offer.

The functions performed at the single and multi-line AWOS are the same. The bar code OCN on the package is scanned and the offer data (weight, cube, tran portation mode, etc.) is determined. Once the system determines the mode of transportation it sends information to the printer at the appropriate label station. Note also that the design has a divert that allows balancing of work between the two multi-line AWOS stations. However, cross-leveling of work cannot take place between the single line AWOS and multi-line AWOS because of the different type of conveyors required for cartons versus jiffy bags.

f. Label Stations

If the package is to be shipped via UPS, RPS, USPS, or other parcel post mode, it will be diverted down the proper accumulation conveyor in the outbound shipping area in bin packing. If the package is going by freight it is transported to the small freight mezzanine in the LTL packing area. The label station operator matches the carton with the appropriate label and attaches the label.

Which documents are printed depends on the mode of transportation. The military shipping label (MSL, DD Form 1387-1a) (Figure 9) is printed for all containers. An automated packing list and some additional labeling may be required based on whether the item is weapon system pouch, number insured, small parcel air, etc. Once all the labeling and documentation is complete, the operator places the packages on the outbound conveyor.

3. Data Development

The data development is broken into three main areas: workload characteristics, equipment characteristics and time standards for the different workstations.

Figure 9

MILITARY SHIPPING LABEL

1. TRANSPORTATION CONTROL NUMBER

W26AEK80130356XXX

2. POSTAGE DATA

POSTAGE AND FEES
PAID DEFENSE
LO""STICS
F EN Y DOD-334

3. FROM

DEFENSE DEPOT OGDEN
OGDEN UTAH SW3400
OFFICIAL BUSINESS PENALTY FOR PRIVATE USE $300

4. TYPE SERVICE

P/P

5. SHIP TO POE 0221599 Z42VA

W26HBK CENTRAL RECEIVING POINT FT LEE VA
CRP WHSE T7126
FT LEE VA 23801 5171

6. TRANS PRIORITY

3

7. POD

8. PROJECT

9. ULTIMATE CONSIGNEE MARK FOR

W26AEK

INSTAL PBO
CRP WHSE T7126
FT LEE VA 23801 5171

10. WT.

00000

11. RDD

13. CUBE

0000.0

12. CHARGES

14. DATE SHIP

88025

15. FMS CASE NUMBER

16. PIECE NUMBER

00001

17. TOTAL PIECES

00001

Current data on the workload such as number of single line shipping units, distribution of shipping unit size, number of IPG 1's, 2's, 3's was obtained from DDMT from a standard DWASP F058 report (a sample is provided in Figure 10). Initial model runs were performed using a five day sample.

However, when the interim model results were presented to DDMT they questioned some of the data, in particular the small number of large shipping units. We proceeded to capture a total month of data and analyzed it. There was not enough of a difference to warrant rerunning the bin packing model. Therefore all results for bin packing reflect the earlier data development.

On the other hand, we did adjust the input data to the LTL model to reflect some larger shipping units that would be packed in triwalls. The number of large shipping units is critical because it determines what portion of the workload is going triwall versus what passes through bin and LTL offer and label. Since cube and weight data is not available on each individual bin shipping unit, we made the assumption that any shipping unit of over 70 lines would be packed in the triwall area. Hence, the greater number of large shipping units, the greater number of lines going triwall and ultimately less work for the label stations on the LTL mezzanine.

The goal workload for the system was set at 10,000. In order to determine the distribution of the shipping unit sizes for the goal workload it was unreasonable to use the same distribution as for current workload since increases in the number of customers served would be minimal. We employed the same methodology as used in the DDOU DWASP Study that increased the current distribution by a random factor (from 1 to 2.5) on a shipping unit to shipping unit basis. This placed most of the additional workload into larger shipping units but also allows for some limited growth in total number of shipping units per day over current levels. Details of the data used in the simulation are presented in Appendix A. A summary of the goal workload characteristics is provided in Table 7. Figure 11 represents a more detailed graphical representation of the workload requirements by section. Figures are generally rounded off.

Table 7

GOAL WORKLOAD CHARACTERISTICS

	LINES	SU'S	SINGLES	MULTI SU'S	LINES/MULTI
IPG1-Batch 1	1040	700	610	90	4.9
IPG2-Batch 2	1205	713	587	126	4.9
IPG3-Batch 3	5704	761	574	187	27.6
IPG3-Batch 4	2051	1166	914	252	4.5
DAILY TOTAL	10000	3342	2687	655	11.1

Figure 10

SAMPLE F058 REPORT

```
1UWF058          WORKLOAD DATA (MECHANIZED COMPLEX)                                    FRC
06   DATE 08.16.88.229   PAGE 00005
0

0          LGC - 6

0          BATCH NUMBER - 68                  TOTAL S.U. - 00226               SINGLE LINES - 00144
TOTAL LINES - 01444
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0056       00001                  0052      00001                  0043      00002
 0042      00001
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0040       00001                  0035      00002                  0033      00001
 0031      00001
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0030       00001                  0028      00001                  0027      00002
 0026      00001
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0021       00001                  0019      00002                  0018      00001
 0017      00003
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0016       00004                  0015      00002                  0014      00004
 0013      00004
0          SU SIZE - NUMBER                   SU SIZE - NUMBER                 SU SIZE - NUMBER
SU SIZE - NUMBER
0           0012       00006                  0011      00006                  0010      00004
```

Equipment characteristics and station processing times were provided by DESO and are detailed again in Appendix A. The critical ones are presented in Tables 8, 9 and 10. The computer response time in Table 9 is the time from when a scan is made by a bar code reader to the time the computer sends the required information to the printer to begin printing. The percentage of lines going freight was an estimate provided by DDMT and includes consideration of future implementation of the Enhanced DLA Distribution System (EDDS) which increases current percentages of bin items going freight.

Table 8

CRITICAL STATION TIMES

Station	Average Processing Times
Input Orientation	5.5 secs/ctn
IRRD Regular	10.5 secs/line
IRRD Exception	26.3 secs/line
Single Pack	66.0 secs/line
Multi Pack	33.8 secs/line

Table 9

CRITICAL EQUIPMENT TIMES

Equipment	Average Processing Time
Computer Response	7.2 secs
IRRD Printer	4.5 secs
Automatic Sealer	8.0 secs
Dunnage Dispenser	12.0 secs
AWOS-single line	3.0 secs
AWOS-multi line	6.0 secs
Label Print	3.5 secs

Table 10

MISCELLANEOUS INPUT DATA

Tilt Tray/Scan Error Rate	.05%
Percentage to Freight	70%
Containers/Multi SU	1.28
Containers/Single SU	1.12

B. Analysis

1. Expected Value Results

The expected value calculations for the baseline system yielded some interesting conclusions. By baseline we mean the system as designed and using 10,000 items for packing as the goal workload. Table 11 details the results of those calculations. The results for the label stations ranged from 0.3 to 3.8 hours of work daily per station.

Table 11

BASELINE EXPECTED WORKLOAD

Section	Hours per Station
Input Orientation #1	11.5
Input Orientation #2	3.5
IRRD Regular	4.2
IRRD Exception	.0
Single Pack	5.0
Multi Pack(18 packers)	3.8
Multi Dunnage	1.3
Multi Seal	1.0
Single AWOS	2.5
Multi AWOS	.7
Parcel Post Label Stations	.3-3.8

Immediately one can make several conclusions. Clearly a problem exists in the workload balance between the input orientation stations. One side is receiving the flow from the carousels and the narrow aisle bin storage where the majority of the bin picks are generated. Pallet racks and LTL are the work source for the other side. A work-around for this problem would be to have the overloaded worker periodically push items over to the other station. This is clearly a less than desirable alternative. The daily average amount of work is already at 7.5 hours per station using standards that did not take into consideration pushing items from one side of the input chute to the other. Furthermore, any slack time that would occur between drops or between item arrival would aggravate the situation. Under this goal workload scenario the area is a potential bottleneck.

Secondly, the multi-line packing area appears to be overdesigned. There are a total of 95 multi-line packing stations. Manning these with 18 packers results in an average utilization of 3.9 hours per person per day.

On the other hand, one could argue that the additional chutes are needed for shipping unit separation. The largest average number of shipping units in a batch is 252 (see Table 7). There are 85 nontriwall multi-line packing stations so this averages 2.9 shipping units per chute for that batch. The packers can easily separate 3 shipping units in a chute.

Averages do not provide a complete picture of the situation, however. The other factors that influence how many shipping units are in a given batch are dynamic factors. On a given day, depending on the variability in shipping unit sizes, there could be significantly more than 252 shipping units in a given batch. Another consideration is the number of shipping units open (i.e., not yet completely packed) at a chute. If a chute gets 5 shipping units in a batch, some of these will be closed out during the drop and not all 5 may be in the chute at the same time. These are all dynamic factors that were examined with the simulation.

2. Simulation Results

In running the simulation we assumed that a solution for balancing the work between the two input orientation stations had been found. Otherwise, the queue buildup for one station would have grown continuously and caused the simulation to abort due to lack of space on the computer. Additionally, the expected value calculations led us to assume that only 65 of the 95 multi-line packing chutes were needed and only 8 of the 10 single line chutes. Eighteen mutli-line packers and eight single line packers manned the packing stations with jockeying allowed in the multi-line area.

Table 12 depicts the significant summary results from the simulation model. The daily averages are averaged over all the stations in that section and are for a daily 8-hour period. The throughput numbers are measured in the units meaningful for that section. Thus, for packing the throughput is the number of lines packed and for mulit-line seal it is the number of cartons sealed. The queue size statistics are average sizes per station.

When these throughputs are compared to the requirements as presented in Figure 11 we see that the system easily meets the requirements. Note that multi-pack includes triwall packing. The queue sizes for the orientation stations together average to about 200. If you examine the queue sizes for one of the input orientation stations, as depicted in Figure 12, each queue grows to about 200. However, the chute is large enough to accommodate that queue. Notice the reduction in the queue sizes that occur during the intervals between drops.

Table 12

SIMULATION RESULTS-REDUCED PACKING STATIONS

Section	Throughput	Queue Size	Utilization
Orientation	10,000	100	95%
IRRD	10,060	0	58%
Single Pack	2,690	21	78%
Multi Pack	7,310	22	46%
Multi Dunnage	860	1	19%
Multi Seal	860	0	12%
AWOS Single	2,984	0	32%
AWOS Multi	860	0	9%
Mode Label	1,390	1	20%

The other area of concern that was discussed above was the number of multi-line packing stations. The two factors that were to be examined using the simulation was the variability in the number of multi-line shipping units contained in a given batch and the number of shipping units open over time.

To examine the variability in the number of shipping units in a day we only looked at batches 3 and 4 since the maximum number of units will occur in one of these. The histograms in Figure 13 provide the distribution of the number of shipping units in batches 3 and 4 over a 100 day period. There is significant variability in the batch 3 values since very large shipping units can occasionally occur and the system tries to keep the total lines in the batch fairly constant. Most of the shipping units in batch 4 are fairly small and thus the total number does not vary much. The maximum number of shipping units in a batch over all 100 days was 355 and occured in batch 4. Since the shipping unit sizes for this batch are fairly small the number in each chute is fairly uniform. Spread out over 85 packing chutes yields an average of 4.18 units per chute. If the number of chutes is reduced to 65, the maximum number of units coming to a chute during the batch is 5.5.

Figure 11

GOAL WORKLOAD REQUIREMENTS

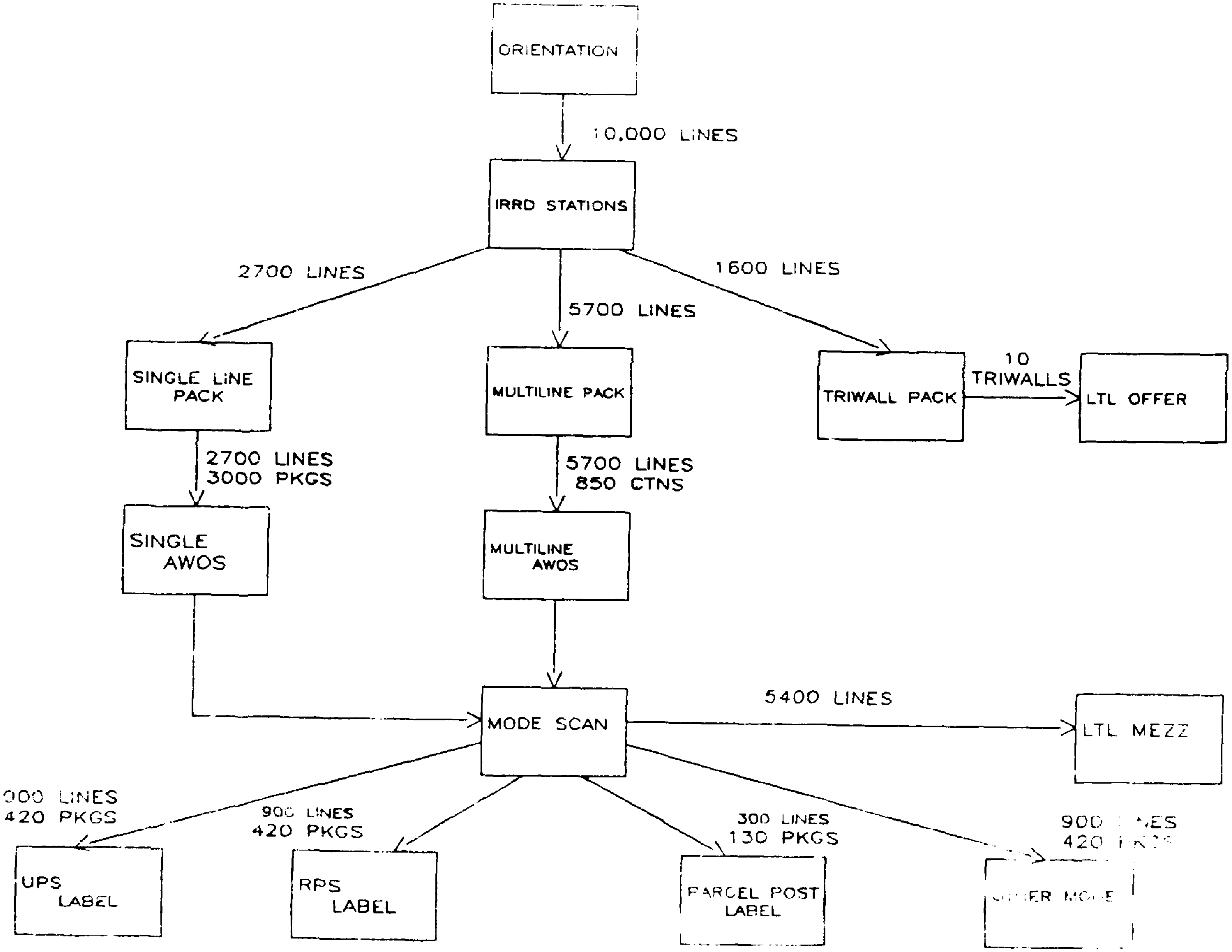


Figure 12

SAMPLE QUEUE FOR ORIENTATION

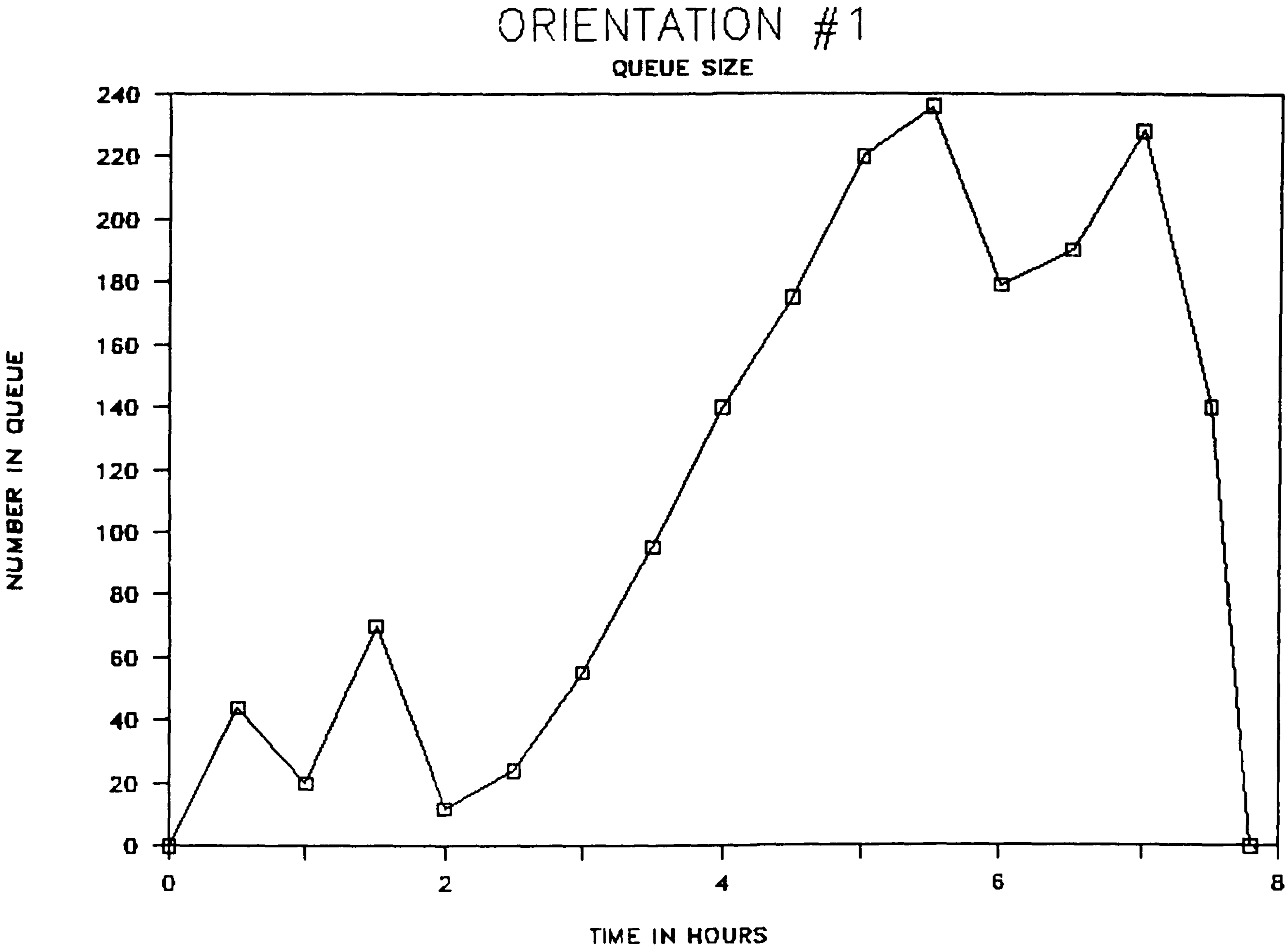
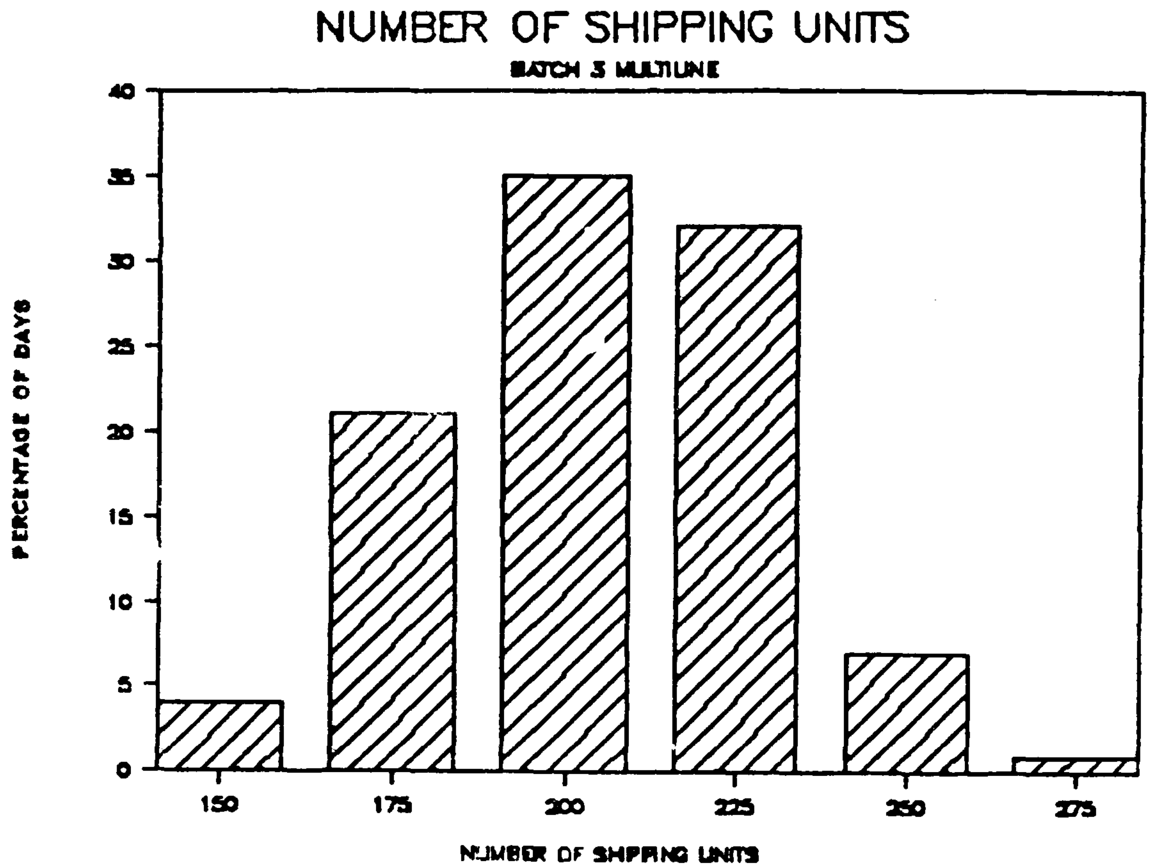
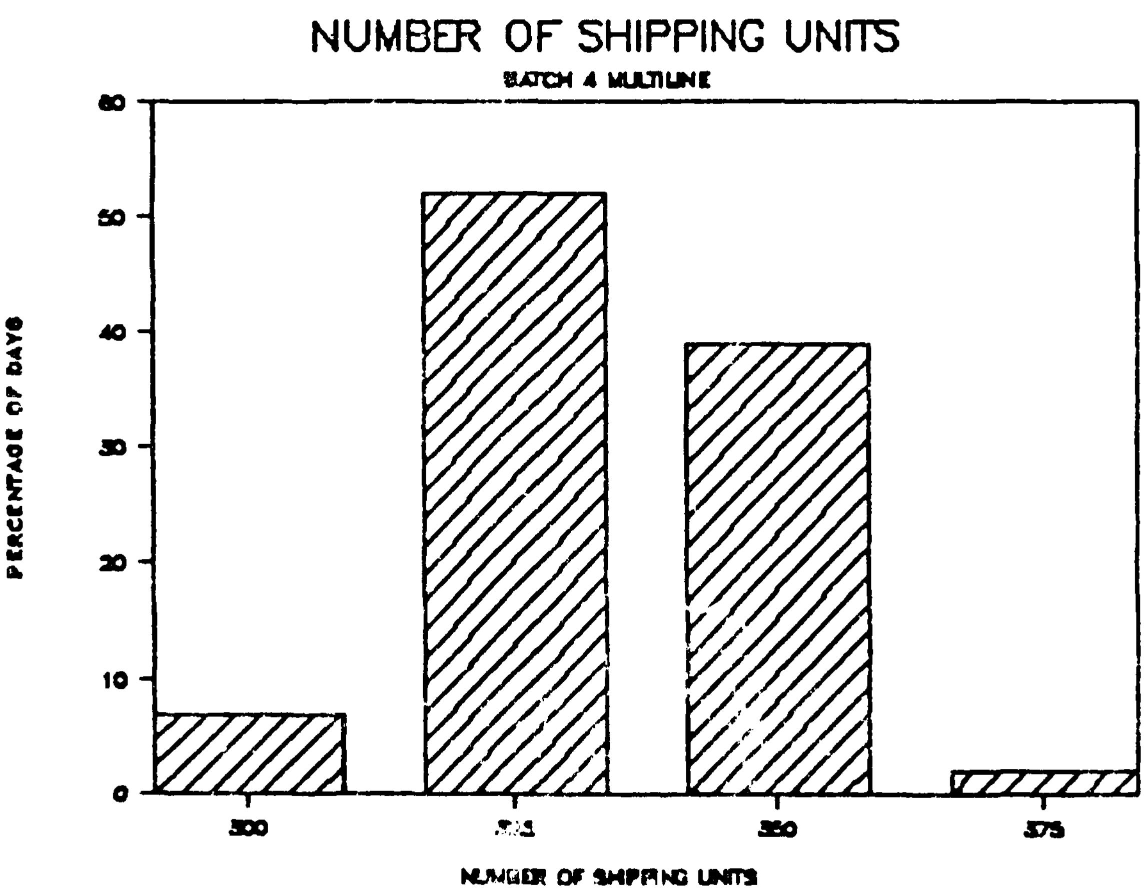


Figure 13

DISTRIBUTIONS ON NUMBER OF SHIPPING UNITS





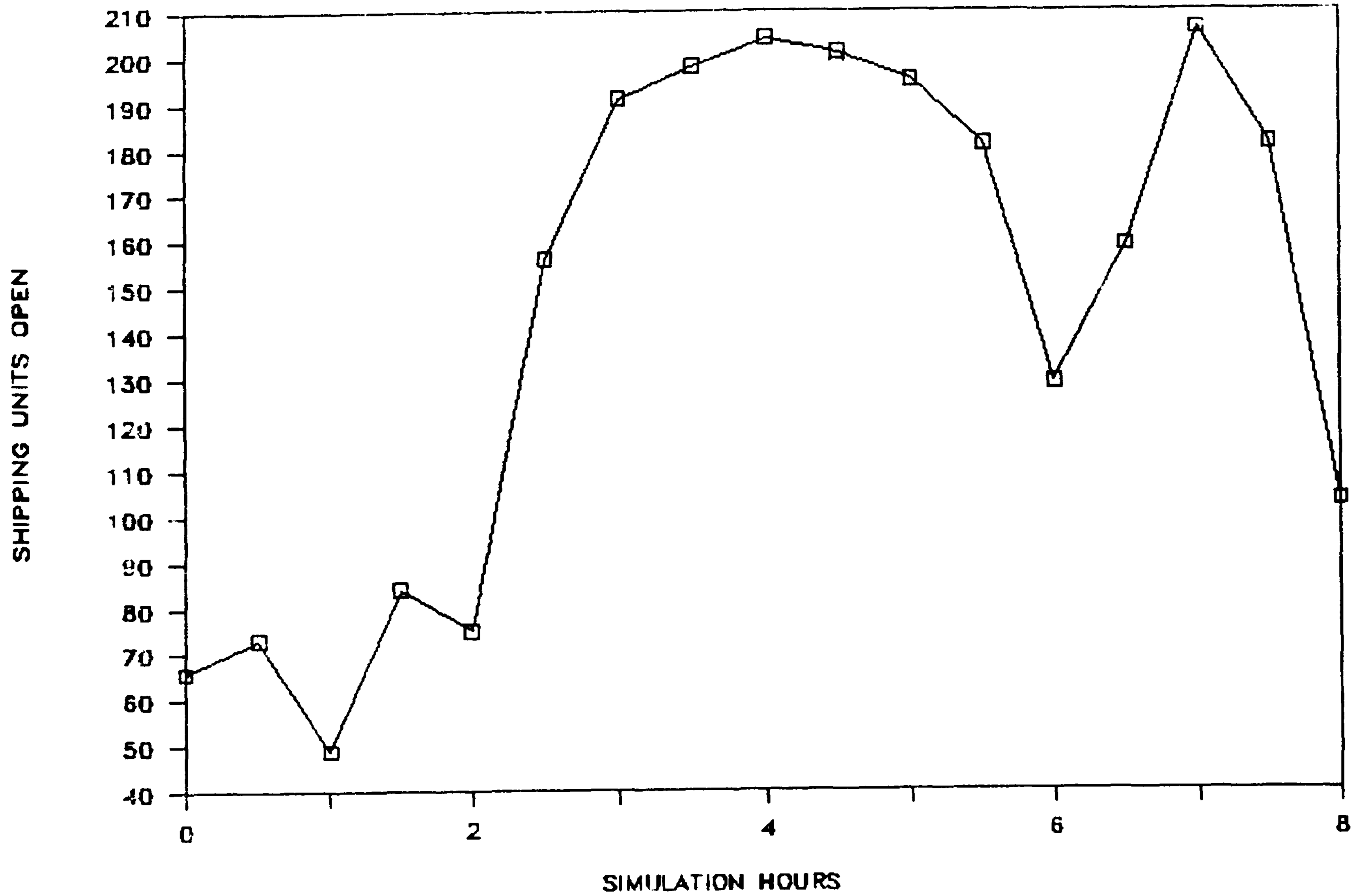
The analysis above yielded insights into the maximum total number of units that may come down a chute during a batch. However, not all these units will be in the chute at the same time since the packer will close some out as he packs. Also the arrival of items beginning a new unit is spread across the entire time for the batch. To investigate how many units are open, i.e., at least one item for the shipping unit has been sent down a chute and yet not all items in the unit have been packed, we kept statistics on the total number open for all chutes at any given time. The average was 183 over the entire day with a maximum value of 301. A graph of the number open for a sample day is presented in Figure 14. The maximum occurred in batch 4 and again looking at 85 chutes yields an average of 3.5 units per chute. If only 65 chutes are utilized, then 4.6 units are open at a maximum. This is still within an acceptable level.

Figure 14

NUMBER MULTI-SHIPPING UNITS OPEN

TOTAL MULTI SU'S OPEN

DAY 5



APPENDIX A

DDMT Bin Packing Simulation - Input Distributions

Table A-1

WORKSTATION PROCESSING TIMES

Process	Time in Seconds
Input Orientation	TRIAG(5.1,5.5,5.9)*
IRRD Regular	TRIAG(10.,10.5,11.)
IRRD Exception	13.0 - 3% 19.5 - 90% 120.0 - 7%
Single Pack	TRIAG(67.2,66.,69.3)
Multi Pack	TRIAG(32.1,33.8,35.5)
Packing Jockey	TRIAG(6.7,7.,7.4)
Offer Label UPS	TRIAG(19.8,20.8,21.9)
Offer Label RPS	TRIAG(30.9,32.5,34.1)
Offer Label USPS&PRI-MAIL	TRIAG(11.4,12.,12.6)
Offer Label EXPRS	TRIAG(40.3,42.4,44.5)
Offer Label WSP/SPA/No.INS	TRIAG(73.8,77.7,81.6)
Outbound Ship Error Line	14.8- 3% 15.6-90% 120.0- 7%

* TRIAG means triangular distribution

Table A-2

EQUIPMENT PROCESSING TIMES

Equipment	Processing Time (Secs)
Computer Response	UNFRM(3.,5)* -90% UNFRM(20.,40.)- 8% UNFRM(30.,90.)- 2%
IRRD Printer	TRIAG(4.1,4.5,4.9)
Multi Seal	TRIAG(7.2,8.,8.8)
Multi Dunnage	TRIAG(10.8,12.,13.2)
AWOS-Single	TRIAG(2.7,3.,3.3)
AWOS-Multi	TRIAG(5.4,6.,6.6)
Label Print	TRIAG(3.1,3.5,3.9)

Table A-3

WORKFLOW BREAKOUTS

Percentage to IRRD Exception	7.5%
Percentage Multi Cartons Need Dunnage	95.0%
Percentage Multi Cartons Need Seal	100.0%
Percentage Multi Cartons Need Strap	50.0%
Percentage Singles in Cartons	77.5%
Percentage Single Cartons Need Dunnage	99.0%
Percentage Single Cartons Need Taping	100.0%
Percentage Single Bags Need Stitching	100.0%

Table A-4

MISCELLANEOUS INPUT DATA

Average Number Cartons per Multi Shipping Unit	1.28
Average Number Cartons per Single Shipping Unit	1.12
Conveyor Speeds:	
Incline from Entry to IRRD Mezzanine	60 feet/min
IRRD Mezzanine Conveyors	120 feet/min
Tilt Tray Sorter	185 feet/min
Packing Takeaway	65 feet/min
Offer Area Conveyor	120 feet/min
Offer Takeaway	85 feet/min

Table A-5

EQUIPMENT PROCESSING TIMES

Equipment	Processing Time (Secs)
Computer Response	TRIAG(6.,8.,10.0)
IRRD Printer	TRIAG(4.5,4.6,4.7)
Multi Seal	TRIAG(10.5,11.,11.5)
Multi Strap	TRIAG(7.7,16.,24)
Route Slip & APL Printer	TRIAG(8.2,8.3,8.4)
MSL Printer	TRIAG(2.8,3.0,3.2)

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13. ABSTRACT *(Maximum 200 words)*

Defense Depot Memphis Tennessee (DDMT) has for a long period of time operated with packing areas in many parts of the depot. That concept has changed recently, and they are consolidating operations as much as possible to take advantage of the associated economies. In addition, the requirement to upgrade and add on equipment to support the introduction of the DLA Warehousing and Shipping Procedures (DWASP) presented the opportunity to effect the consolidation. This plan materialized in the form of the DDMT Central Pack design for less than truckload (LTL) packing and bin packing operations. The purpose of this study was to perform a computer simulation of the proposed design to determine if goal throughputs could be met and to make recommendations on system improvements and modifications. This report documents the results of the simulation effort.

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